Exploring the Biomechanics of Red Blood Cells: Paving the Way to Efficient and Physiological Modeling of Erythrocytes in Shear Flow

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During circulation, red blood cells (RBCs) experience shear stress. While RBCs are mechanically robust, extreme flows may compromise the spectrin network and lipid bilayer, leading to hydrophilic pore formation that can expand and cause hemolysis. Understanding spectrin mechanics and pore formation is of great importance in biomedicine. Over 1.7 billion people suffer from blood-related disorders or are life dependent on ventricular assist devices (VADs). Such VADs and microfluidic blood testing devices must be appropriately designed to keep RBCs intact, while gene and drug transfection therapies rely on transient RBC poration. The experimental scope of this project involved reverse aspiration to squeeze RBCs under high shear and study hemolysis using fluorescence microscopy. An alternative approach under investigation utilizes UV lithography to design long residence channels for spectrin studies using atomic force microscopy. Computational modeling of RBCs under pulling forces provides understanding of spectrin deformation. However, since atomistic simulations are costly, inefficient and largely inaccessible, a coarse-grained (CG) model was developed and validated. Pore formation was studied through development of a DPPC (1,2-dipalmitoyl-sn-glycero-3-phosphocholine) bilayer model subjected to equibiaxial quasistatic stretching via a CG forcefield. Effects of bilayer composition (cholesterol/asymmetry) and increasing shear rates were studied via potential energy, partial density, and surface tension analyses. The goal of this research is to produce both experimental and computational insights into strain-induced RBC poration to explain unknown blood disease mechanisms, allow for better VADs, or explore transient pores for targeted drug delivery.

Awards Won:

Third Award of $1,000